PART 5

LM FOOD CHAIN

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Chapter 1. Executive Summary

This part of the report documents the food web bioaccumulation model developed for the Lake Michigan Mass Balance Project (LMMBP). The model established dynamic relationships between polychlorinated biphenyl (PCB) concentrations in the exposure environments and result PCB levels in the fish food webs of Lake Michigan. The primary objective of this work was to provide practical modeling tools to predict toxic PCB levels in lake trout and coho salmon in response to projected water quality improvements for the lake.

The model was based upon available theory and data characterizing the bioaccumulation of toxic chemicals in fish and other aquatic organisms. A detailed description of the model development is provided in the document. Extensive collections of data on lake trout and coho salmon food webs in Lake Michigan were conducted to facilitate refinements of model parameters to site-specific conditions. Forty congeners or congener groups of PCBs were targeted for the model calibration or parameter refinements. These PCB congeners represented toxic chemicals covering a wide range of hydrophobicity.

The food web model was calibrated with PCB data collected in 1994 and 1995 for three lake trout food webs at Sturgeon Bay, Sheboygan Reef, and Saugatuck. The lake trout sub-populations in these three biota zones were believed to be appropriate representations of lake trout in Lake Michigan. Model calibration was also performed for a lake-wide coho salmon food web. During the model calibration, model parameters were refined to achieve an adequate agreement between model calculations and observed PCB data for a food web. In this study, the focus of model calibration was not limited to top predators nor to toxics with certain hydrophobicity. The model parameters were systematically optimized for all species at various trophic levels and for PCB congeners of a wide range of hydrophobicity. Extra care was taken to ensure the refined parameter values were consistent with the hydrophobicity of individual PCB congeners and with the trophic position of individual species. Satisfactory calibration results were achieved for the lake trout food webs at Sturgeon Bay and Saugatuck. Although no formal validation was possible due to additional requirements of large amount of PCB congener-specific field data, the calibrated food web models for Sturgeon Bay and Saugatuck were confirmed in some degree by the identical values of calibrated parameters between these two models.

The availability of a complete account of observed data for each food web made this model calibration probably the most thorough process among similar efforts. Although PCB concentrations in lake trout or coho salmon was the endpoint of the model computation and the focus of most model applications, we believe that the food web model with parameters “fine-tuned” for species at all trophic levels can be used to target any desirable species in the food web with a high degree of confidence. Also, the food web model was capable of assimilating toxics with various hydrophobicities. In fact, no food web model intended to simulate as many toxic chemicals with diverse hydrophobicity has been previously developed.

We believe that the food web model capable of simulating congener-based PCB dynamics in fish food webs provided a useful tool for the development of more effective load reduction plans or total maximum daily loads (TMDLs) targeted to priority PCB congeners, instead of traditional category-based load reduction plans targeted to various contaminant sources. The results of the PCB congener-based model simulations also help to better understand toxic chemical behavior in food webs.

The calibrated food web model was used to perform several model simulations for PCBs in lake trout food webs at Sturgeon Bay and Saugatuck. These model simulations depicted dynamic responses of individual PCB congeners in the food webs to different PCB exposure input. Hypothetical long-term PCB exposure scenarios for the food webs at the Sturgeon Bay and Saugatuck biota zones were generated by the water quality model LM2-Toxic corresponding to different management choices for the reduction of PCBs into the Lake Michigan ecosystem.

For each long-term PCB exposure input, similar model responses were observed for these two biota zones. As an example, the temporal responses of individual PCB congener-based concentrations in adult lake trout at Sturgeon Bay associated with constant external PCB loadings are presented for discussion. The expected total PCB concentrations in adult lake trout at Saugatuck in response to various hypothetical PCB exposure inputs are also presented. Given the exposure PCB concentration time functions provided by the LM2-Toxic, the model simulations suggested that without further intervention, the total PCB concentrations in adult lake trout (5.5 year-old) was expected to reach the target level of 0.075 ppm in 2026 for Saugatuck biota zone and in 2032 for Sturgeon Bay biota zone.